

# **Water Supply and Sanitation Sector Cost-Benefit Analysis Guidance**

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## 1. Introduction

MCC is required by its statutory regulations to conduct cost benefit analysis (CBA) and to calculate the economic rate of return (ERR) on projects supported through country compacts. ERRs form a critical part of the project approval process and are required to equal or exceed a threshold level of ten percent over the medium term. To clarify methodology and to improve the consistency across country compacts, the division responsible for estimating ERRs is developing a series of reports outlining methodology for each major investment sector. This current report is the first and covers Water, Sanitation, and Hygiene (WASH) projects. Other sector CBA methodology reports are forthcoming. The guidelines aim to help MCC economists better understand the methodological tools available, and to provide greater methodological clarity to external practitioners. This should help to provide more consistent application of CBA methodology.

WASH infrastructure projects can be divided into three basic categories: production and treatment, transmission, and distribution of water. Production and treatment projects build or rehabilitate central water pumps or sewage treatment plants. Transmission projects build or rehabilitate systems that transmit water from central pumping stations to distribution systems. Distribution projects build or rehabilitate systems that deliver clean water to consumers in greater volumes, on a more reliable basis, and/or connect new consumers to the system. When distribution by pipeline is infeasible, clean water can be distributed by digging wells or boreholes. WASH sanitation projects improve public sewer systems (including building or rehabilitating sewage treatment plants), connect households to sewer systems, provide households with septic tanks, or provide latrines.

Donor interventions in WASH projects can be justified on economic efficiency grounds by (i) market failures in the provision of clean water and sanitation, due to information externalities related to hygiene and health, and environmental externalities from water use and inadequate sanitation practices; and/or the natural monopoly characteristics of water and sanitation systems; or (ii) government or public service failures resulting from poor sector or utility governance, including mispricing of water and sanitation services, costly and/or unreliable service provision, and/or costly system losses.<sup>1</sup> Health externalities occur because providing cleaner water to existing customers, and extending access to clean water to new customers, can lower the overall incidence of water-borne diseases. The private benefit to an individual investing in access to clean water is less than the total societal benefit of one more individual having access to clean water. Due to such externalities, provision of WASH investments tends to be lower than the socially optimal level (i.e., the level at which the marginal cost of providing the infrastructure is equal to the marginal benefit to the society as a whole).<sup>2</sup> In addition, countries may often misallocate their available water resources across uses and over time. Too much water may be used in low return activities, and too little in high return activities; when this results in rationing or threatens water scarcity in the near term, the failure to address market failures adequately can result in a sub-optimal growth trajectory.

Insufficient quantity and quality of water and sanitation infrastructure, sometimes combined with a lack of knowledge and practices of good hygiene, has been identified as a binding constraint to economic growth in several MCC compact countries. In other cases, water scarcity has been identified as binding to growth due to a combination of low natural endowments and either conservation failures, allocation inefficiencies, or both. Specific indicators may include household and firm use of private labor, private vendors, or tanker services to obtain water at volumes and costs that are high relative to comparator countries; high time use by households to collect water that imply a large opportunity cost of access; large estimated disability adjusted life years (DALYs) due to water borne illnesses, particularly diarrhea; and high collection inefficiencies and system losses combined with high unmet demand at a cost-reflective price.

These indicators are often supported by an unfavorable level and trend in: i. water and sewage service coverage relative to benchmark countries; ii. firm perceptions that water is a constraint to investment; iii. evidence of poor sustainability of water service delivery due to underpricing or low fee collection (with the resulting low maintenance and reinvestment in the system); and iv. country-specific tax, investment and regulatory problems. To relieve the constraint, compact countries typically request that MCC invest in infrastructure for delivering clean water, and these are usually combined with sector reforms to improve system sustainability and sector performance in a more lasting, systemic way.

To realize the benefits of WASH projects, beneficiary behavior often must change (e.g. end user hygiene practices). As a result, WASH projects are frequently accompanied by a local outreach strategy.<sup>3</sup> When feasible the outreach strategy is integrated into the project, but at times it is done as a standalone project. When integrated into the project, a “behavior change” parameter must be included in the ERR, informed by evidence or “expert judgment,” that can be evaluated afterwards.<sup>4</sup>

Since one of the goals of WASH projects is to reduce potential beneficiaries’ exposure to contaminated water, drainage projects should be considered WASH projects. To the extent that drainage projects eliminate flooding, they may also reduce property damage and value added lost to business closures, as well as time lost in congested traffic via time-consuming detours.<sup>5</sup> Ideally the cost benefit analysis should be built around a simulation of likely flooding scenarios.

Lastly, recognizing the importance of addressing root causes, activities to improve sector policy, institutional capacity, and governance play an increasing role in WASH projects. MCC compact countries frequently seek assistance in enhancing the performance of their WASH utilities by improving sector governance, the management, commercial and financial viability, service levels, and sustainability of WASH utilities, and/or changing beneficiary behavior (typically hygiene-related) to maximize the benefits beneficiaries get from already existing WASH infrastructure.

These guidelines will describe the typical project logic for WASH projects and the associated costs and benefits, as well as typical institutional reform issues. This is a living document that will be updated periodically as necessary.

## 2. Simple Taxonomy of WASH Project Logics

WASH projects can be generally categorized by their program logics linking outputs that are funded by Compacts to potential benefit streams, as shown in Table 1.

Table 1: WASH Project Taxonomy

<b>Project</b>	<b>Main Potential Benefit Streams</b>
Central infrastructure (upgrading central treatment and distribution centers)	Decreased technical losses, increased supply, lower costs of service, improved reliability, and/or lower all-in water prices for consumers. If consumption increases, increased consumer surplus.
Reform of sector governance, utility governance and/or ownership, regulation, financial arrangements	Decreased commercial losses, more sustainable service or system expansion, leading to higher future supply and/or lower costs of service (or substitution from higher cost sources) for consumers.
Infrastructure Extension (extending water and sewer pipes to unserved neighborhoods)	Improved health outcomes, decreased time gathering water for water extension projects
Other water infrastructure (boreholes, wells, etc.)	Improved health outcomes, decreased time gathering water, greater production
Other sanitation infrastructure (latrines, septic tanks, etc.)	Improved health outcomes

Project logics are logical models that outline the cause and effect relationships between the outputs provided by the project and the outcomes underlying the beneficiary streams captured in the economic analysis of a project. Included in these cause and effect relationships are assumptions upon which the next level of outcomes depend. For example, whether health outcomes are improved by providing increased access to clean water may depend on a number of behavioral changes necessary to prevent contaminants from being introduced into clean water in the household. This assumption about the connection between access to clean water and health impacts is critical to the cause and effect chain (“results chain”) and to avoiding leaps of logic in its articulation.

As with all logics, the particular operational context is paramount—there is no such thing as a definitive or standard logic. For example, if evidence demonstrates that households generally do not practice safe hygiene, then an accompanying activity may be required to address this, and “safe hygiene practices” would become a medium-term outcome targeted by the activity, as opposed to an assumption.<sup>6</sup> A project logic is a living guide that should be responsive to feedback from the context in which it operates.

Three examples of project logics are provided here for time savings, health benefits, and cost savings. WASH infrastructure provides clean water that, combined with proper hygiene practices, can significantly reduce the burden of water-borne diseases in a country’s population, increasing the overall productivity of

the country's endowment of labor. It can also significantly lower the amount of time households must spend gathering water. Lastly, policy and institutional reform WASH projects can improve the productivity of capital invested in the sector (e.g., by implementing a maintenance program to reduce physical leaks), and thereby lower the cost of water delivery to the utility's customers, and may increase service quality and expanded service, depending on the context and the reform in question.

### Time Savings from Collecting Water

In some countries women and children are the main household members responsible for gathering water. One of the main benefit streams from WASH projects, particularly in rural settings, is reducing time spent gathering water. Absent data about children's wages and the opportunity cost of children's time not spent in education and other enrichment activities, we assume that time spent by children getting water is substitutable with women's time – if the children don't do this chore, the women in the household have to do it. For the time-savings benefit stream of WASH projects, the project logic may look like that in Table 2.

Table 2: Example Project Logics for Time Savings from Collecting Water

<b>Time Savings (for a networked WASH system)</b>		<b>Assumptions</b>	<b>Indicators</b>
Infrastructure Output	New pipes connecting households to existing network installed		Length of pipe laid
Project Output	Households that previously had to leave house to collect water are now connected to the new pipes	Last mile connections are either affordable or paid for by the local government, and households choose to connect	Number of households connected
Short Term Outcome	Switching from other sources to tap water and time savings accrued		Tap water consumption Time spent collecting water
Long Term Outcome	Time savings used in productive (market or domestic) or leisure activities	No barriers to entry to labor markets – leisure, if chosen, is chosen voluntarily	Value of time saved, valued according to guidelines
Goal	Increase in household		Household income or expenditures /

<b>Time Savings (for a networked WASH system)</b>		<b>Assumptions</b>	<b>Indicators</b>
	income/value added from home production/leisure good consumption		consumption

### Health Benefits

When the provision of water to the populace is below the social optimum, there may be health benefits from increasing access to clean water. These health benefits depend on new water and sanitation users connecting to the system and/or higher levels of water use per capita. However, the expense of accessing clean water is often prohibitive for poor households, many of whom cannot access the necessary finance for a connection, and utilities may be financially incapable of financing connections through user fees. In many cases, health benefits also depend on households' adopting new hygiene practices. The project logic must explicitly account for how new users will be connected to the new infrastructure, and what will lead to changes in their hygienic practices, if necessary, to realize benefits.<sup>7</sup>

It should be noted that water systems that do not maintain continuous 24-hour pressure can allow contamination from groundwater to seep in, defeating the purpose of the project. The economist should always ask water sector counterparts on the team if achieving 24-hour pressure is necessary and accounted for in the project logic.

Table 3: Example Project Logic for Health Benefits

<b>Health Benefits (for a networked WASH system)</b>		<b>Assumptions</b>	<b>Indicators</b>
Infrastructure Output	New pipes connecting households to existing network installed		Length of pipe laid
Project Output	Households that previously had to leave house to collect water are now connected to the new pipes	Last mile connections are either affordable or paid for by the local government, and households choose to connect	Number of households connected
Short Term Outcome	Households reduce consumption of contaminated water	Households engage in safe water storage and	Tap water consumption Tested water is not

<b>Health Benefits (for a networked WASH system)</b>		<b>Assumptions</b>	<b>Indicators</b>
	in favor of clean water	handling practices so tap water is not contaminated	contaminated
Long Term Outcome	Incidence of water-borne diseases declines		Incidence of infectious diarrhea, stunting/wasting
Goal	Decrease in DALYs lost		Days spent suffering from/caring for diarrhea declines, under 5 deaths decline, stunting/wasting declines

### Project Logic for Cost Reduction/Improved Access

In some countries, the main problem associated with water is its overall scarcity, and the benefits associated with health or time savings are relatively low compared to reducing the cost of water. In some cases benefits can be measured with “revealed preferences” estimates associated with reducing the costs of water using observations of consumer expenditures on marketed commodities (like bottled water), but in some cases the full benefits are better captured by measuring the increase in consumer surplus resulting from increased water consumption through a stated-preference survey.

Table 4: Example Project Logic for Cost/Reduction/Improved Access

<b>Cost Reduction/Improved Access</b>		<b>Assumptions</b>	<b>Indicators</b>
Infrastructure Output	Repair of partially and fully depreciated pipes		Length of targeted pipe repaired
Project Output	Lower technical losses		Technical losses
Short Term Outcome	Increased revenue per unit of water supplied by utility	Increased water supply to customers is monetized	Utility revenue
Medium Term Outcome	Cost savings are passed on to shareholders, consumers, or	Utility regulatory agency performing price setting function adequately	Water tariffs



<b>Cost Reduction/Improved Access</b>		<b>Assumptions</b>	<b>Indicators</b>
	government	Households connect and stay connected to water and sanitation services and use their new household sanitary facilities accordingly.	
Long Term Outcome	Lower beneficiary expenditure on water		Beneficiary expenditures on water
Goal	Increase in household income		Household expenditures

### Improved Utility Performance and Sustainability

An MCC WASH project may have an institutional improvement subcomponent aimed at improving the financial sustainability of the WASH sector. For example, the “collections ratio” may be a key indicator: the ratio of water supplied that is actually paid for relative to the total volume of billable water. The collections ratio is typically less than one for two reasons: physical losses and commercial losses. Projects to reduce the two types of losses have qualitatively different project logics and, therefore, benefit streams.

Physical losses result when water simply leaks out of the system. Reducing physical losses (including efforts to track and manage the depreciation of assets in order to plan for future maintenance and replacement) is essentially an engineering problem. A reduction in physical losses results in more water reaching customers for the same costs, effectively reducing the unit cost of water provision. In some cases this benefit is calculated as the improvement in the utility’s revenues resulting from the reduction in physical losses. Note that whether these cost savings will be passed on by the utility to beneficiary households will be a critical question for the beneficiary analysis.

The project logic for physical losses will look essentially the same as the one for cost reduction (see table 4).

Commercial losses result when water is deliberately diverted from the system by non-paying users, or when billed users fail to pay their bills. Sometimes commercial losses result in technical losses, when non-paying users drill holes in pipes. Often the utility needs assistance in improving business practices so that non-paying customers can be identified and their service shut off until they pay, although it is often not this simple. Political-level, institution-specific interventions, in addition to the installation of pre-paid meters, may be required to address the problem.

The benefit of reducing commercial losses is more difficult to quantify. Water that is not paid for

nevertheless reaches a consumer, who benefits. A commercial loss can be seen as a transfer from the utility to the non-paying customer. However, the long run financial autonomy of any utility is important to its performance incentives and ability to meet demand, and commercial losses often contribute significantly to a utility's poor financial performance. Often utilities require intervention because they are unable to fund maintenance requirements or acquire new assets. The benefit of reducing commercial losses serves to improve a utility's long run financial performance and sustainability, which can be modelled relative to the "business as usual" (or baseline) situation. The ultimate expected outcomes are lower average user costs, the economic value of reduced fiscal losses, or the benefits of reinvestment and system expansion for businesses and households. Each case must be analyzed based upon the country/sector context and benefit streams calibrated to available evidence on policy and institutional arrangements in the water sector.

A project logic for reducing commercial losses would look like the following:

Table 5: Project Logic for Reduction of Commercial Losses

<b>Lower Costs</b>		<b>Assumptions</b>	<b>Indicators</b>
MCC Output	Institutional reform of utility business practices		completed milestones of utility reform process
Project Output	More rigorous billing and collections practices		Billed vs. collected consumption
Short Term Outcome	Increased revenue per unit of water supplied for utility	Institutional reform is sufficient to improve collections	Utility revenue, cost-recovery ratio
Medium Term Outcome	Utility is better able to fund asset maintenance and acquisition	Improved financial autonomy results in improved service delivery.	Existence of and funding for long term maintenance and asset acquisition plan
Long Term Outcome	Lower beneficiary expenditure on water per unit of consumption, greater reliability, greater water use, or lower tax/donor support to utility	Regulatory agency ensures that any cost savings are passed on to consumers	Beneficiary expenditure on water from survey or utility records
Goal	Increase in household income		Household expenditures

### 3. General Approaches to the Economic Analysis of Potential WASH Projects

Given MCC's mission to alleviate poverty through economic growth, cost-benefit analysis approaches that value and measure benefits as proximate to real incomes as possible are preferred. Depending upon the context, program objectives, and logic, there are two general approaches CBA of WASH projects may take. The **first approach** entails a detailed investigation into separate benefit streams that model effects on real lifetime incomes most directly – in particular, health benefits, time savings benefits, and other cost savings on the part of WASH consumers. These include the effects on productive users – firms, households, and laborers, and in some cases they may include induced benefits of increased production, investment, and labor income beyond the immediate cost savings. Measuring benefits in this way allows MCC to better track and understand the channels of impact on real incomes and to value health externalities. It is the most informative approach for projects in which health and/or nutrition outcomes represent key objectives of the proposed investment.

The **second approach** is to model changes in consumer surplus, a method which in principle combines all private benefits into a single metric. Depending on the logic and objectives of the proposed investment, this may be the most feasible approach. In both cases, changes in producer surplus for domestic providers of WASH services would also be captured in the analysis. As described in MCC's general guidelines for CBA and Beneficiary Analysis, the estimation of benefits consists of a comparison of the benefit and cost streams “with” and “without” the investment or project as proposed.

There is a rich literature that describes the health benefits of supplying communities with clean water and sewage treatment facilities, and a literature describing how to monetize time saved from improved access to water.<sup>8</sup> The magnitude of each benefit stream will depend crucially on the context and design of each project. Although more studies are needed, some previous attempts to value both of these benefit streams find that, on average, time savings account for about three quarters of benefits, with increased productivity from improved health accounting for the other quarter (Hutton and Haller 2004, figures 7 & 8). The MCC experience has been varied – while time savings were in fact about three quarters of benefits in the Zambia compact WASH project, time savings were only 15 and 11 minutes per day per beneficiary in Tanzania and Ghana, respectively.

For all benefit streams, socio-economic data should be gathered, either from the beneficiary population directly or from the compact country's most recent socio-economic survey, which provide information on household income and relevant demographic data (e.g. household size, gender, age and education level of household members, etc.). For purposes of the beneficiary analysis, the beneficiary data should be categorized by MCC's standard income categories.<sup>9</sup> If possible (perhaps during the due diligence stage if compact country data is not available), data should be gathered on time and monetary expenditure on the collection of water from various sources.

This baseline reference estimate can be improved if data on the availability and quality of water for the project beneficiaries is available.<sup>10</sup> Because water can be contaminated at the source of collection,

between the source and the storage container at home, and after it is drawn from the storage container, the quality of water should be sampled from (at least) three sources: the original source of the water, the pipe/faucet that delivers water to the end user, storage containers in the home, and after water is drawn from the storage container for drinking water, cooking, cleaning, and laundry.

Regarding the **second approach**, estimated consumer surplus, benefits may have to be estimated using a revealed or stated preference methodology depending on data availability. For example, beneficiaries' expenditures on bottled water can be used to derive "revealed" willingness to pay for clean water.

If market data are not available to produce "revealed preference" estimates of WTP, then either more indirect methods for estimating health and time savings estimates must be used, or, if even such indirect methods are infeasible, a contingent valuation (CV) survey can be used to estimate stated preferences.

MCC has not developed separate internal guidelines for conducting CV surveys, but adheres to NOAA's 2001 guidelines (NOAA, 2001). NOAA conducts CBA of the Endangered Species Act, which requires them to estimate the benefit of preventing the extinction of species on the endangered species list and have accumulated considerable experience in conducting CV surveys.

### 3.1 Potential Health Benefits

People who are exposed to and consequently ingest contaminated water are vulnerable to a number of diseases, for example: infectious diarrhea, schistosomiasis, intestinal nematodes, and lymphatic filariasis. They can be exposed to contaminated water as a result of ingesting water from contaminated sources, contaminating clean water themselves due to poor hygiene, or exposure to flood waters as a result of poor drainage. Poor drainage can also lead to standing water that can serve as a breeding ground for malaria-carrying mosquitoes.<sup>11 12</sup> These diseases lead to loss of labor productivity in two main ways, death and disability. Malaria and schistosomiasis, for instance, have both death and disability effects.

Infectious diarrhea is the water-borne disease that leads to the most labor productivity loss and can be addressed with water quality and sanitation projects<sup>13</sup>. Diarrhea's main impact is through child mortality – if the victim survives, and if severe stunting does not occur as a direct result, there is no long-lasting disability impact (see table 6). Intestinal nematodes and lymphatic filariasis have almost the opposite effect – both are rarely fatal but have significant disability effects.

Infectious diarrhea not only results in significant loss of life, but significantly contributes to malnutrition in young children (ages 0-5), thus increasing the risk of stunting.

In 2009, the International Initiative for Impact Evaluation (3ie) published a meta-analysis of 65 impact evaluations of WASH interventions aimed at reducing the incidence<sup>14</sup> of childhood diarrhea.<sup>15</sup> The study categorized interventions into five types: water supply, water quality, sanitation, hygiene, and combinations of water, sanitation, and hygiene.

Esrey et al. (1991) found that water supply and sanitation reduced the prevalence of schistosomiasis by

77%, ascariasis by 29%, and hookworm by 4%. Schistosomiasis can be more difficult to track than diarrhea. The best known way to track diarrhea incidence is to conduct a survey, which is relatively straightforward (despite the usual weaknesses associated with relying on recall and etc. in household surveys), while tracking schistosomiasis incidence is harder.

For drainage projects, the estimated malaria reduction can be derived from a study by Castro, et al (2010)<sup>16</sup> that found “restoring and maintaining drains in Dar es Salaam has the potential to eliminate more than 40% of all potential mosquito larval habitats.”

The “without project” estimate of disease incidence requires data on incidence or prevalence of the disease of interest. Preferably, the data should be sampled directly from the beneficiary population, but more aggregated World Health Organization (WHO) data can be the default option if more disaggregated data are not available. Diarrheal disease prevalence is typically available at sub-national levels (importantly – by urban/rural status) through DHS and MICS surveys.

### **Converting Incidence Reduction into Income Using the Human Capital Approach**

To convert reductions in disease incidence into income, we must estimate the effects of lowering death and disability on productivity and life expectancy. For diarrhea, we must also estimate the impact on income of reducing the stunting effect associated with diarrhea’s contribution to malnutrition when it occurs among young children.

Early estimates of benefits used in MCC ERRs focused on costs associated with hospital visits and ad hoc measurements of productivity losses. The problem with this approach is it is not consistent across countries. The Disability Adjusted Life Year is calculated by the WHO in a consistent manner across countries and is therefore one of the few current metrics associated with health-related benefits that can guarantee consistency across WASH projects in different countries.<sup>17</sup> The DALY metric breaks the effects of disease into two components, years of life lost due to death (YLL) and equivalent years lost due to disability (YLD). While not explicitly designed for converting health effects into income, to the extent that the metric is a valid measure of productivity loss, we can assign the value of the marginal productivity of labor to it. Assuming a perfectly competitive labor market, we can use the opportunity cost of time (see discussion above) as the marginal productivity of labor. We use this metric (DALY\*OCT) as the default unless we have specific knowledge of a particular case that allows us to construct a more accurate metric that is still meaningfully consistent across countries.

For stunting, we estimate the lifetime impact that stunting has on education and labor market participation. Stunting is defined as having a height-for-age more than two standard deviations below the median of the NCHS/WHO growth reference (WHO 1995). Alderman et al. (2006) find that stunted children enter school one and a half years later (on average) and enter the workforce 1 year later. The lifetime income impact estimates rely on returns to education and work experience. To estimate these returns, we recommend using a Mincer regression, on which there is considerable literature described in detail in EA’s guidelines for Mincer regressions.<sup>18</sup>

### **Calculating and Valuing DALYs**

The main health benefits from WASH projects come from lower incidences of infectious diarrhea. WASH projects also affect the incidence of other diseases (schistosomiasis, lymphatic filariasis, intestinal nematodes). In the first example below we will describe how the benefits from infectious diarrhea would be calculated, since it is the most common target of MCC interventions. The next example considers a disease that has a more significant disability component.

Disability effects can also be estimated using days of work lost, instead of the YLD component of the DALY (counting both would be double counting). The advantage of this metric is it is relatively easy to measure (either by visiting clinics for administrative data or including relevant questions in a survey). The tradeoff is it will tend to underestimate productivity losses that are not acute enough to result in missed work time. In the case of diarrhea, days of work lost to illness will be very small compared to days lost due to death, especially for children under 5. The economist should use their judgement whether to invest resources in collecting days of work lost data.

YLLs require some estimate of the expected number of beneficiaries expected to die each year and the age at death. Incidence rates (number of cases per thousand in a given time period) and mortality rates (deaths per thousand of cases) are typically calculated by the WHO (sometimes by age group) and can be used to generate these figures. YLDs require estimates of the duration of various diseases, available on page 76 of Mathers et al. (2006) for diarrhea, intestinal nematodes, schistosomiasis and malaria, and page 9 of Ottesen et al. (2008). The YLDs use “disability weights,” available from the WHO,<sup>19</sup> to account for years of life lived in states of less than full health due to a particular disease.

Table 6: Illustrative Example of Incidence, Case Fatality Rate, and Disease Duration (from Zambia WHO data)

<b>Disease</b>	<b>Incidence (/1000)</b>	<b>Case Fatality Rate (/1000)</b>	<b>Duration (years)</b>
Infectious diarrhea	138	2.20	0.016*
Intestinal nematodes	51	0.01	1.52
Schistosomiasis	89	0.04	2.98
Malaria	120**	0.10	2.02
Lymphatic filariasis	15	0	Permanent (i.e., expected lifetime)

\*In other words, the duration of a bout of infectious diarrhea is on average about 6 days.

\*\*But only 5 in urban Lusaka

### **Infectious Diarrhea**

Because time spent actually ill is relatively short for infectious diarrhea (usually a few days, if the patient

survives), the main benefits from reducing incidence of infectious diarrhea can be measured simply through years of life lost (YLLs), making the ERR calculation slightly simpler. YLLs due to infectious diarrhea can be estimated using a breakdown of the host country's population by age, and death rates per 1000 (broken down by age group where feasible).<sup>20</sup>

Next, we need to estimate the reduction in infectious diarrhea incidence that will result from the project. As mentioned above, the current main source for this estimate is a 2009 meta-analysis by the International Initiative for Impact Evaluation (3IE), "Water, sanitation and hygiene interventions to combat childhood diarrhea in developing countries." Figure 5 on page 27 summarizes the effects of various WASH interventions on the incidence of infectious diarrhea. Water quality interventions reduce infectious diarrhea incidence by about 42%, while sanitation interventions reduce incidence by 37%. Although the 3ie study did not examine drainage interventions directly, we currently apply the same incidence reduction estimates as for sanitation interventions, 37%. We will update this recommendation based on the impact evaluation for the Zambia WASH project.

We calculate the number of deaths in the baseline, "without project," and the number of deaths "with project." Incidence rates and death rates will vary by country. The data are available from the WHO or the country's health ministry. The value of deaths avoided each year becomes the benefit stream for health. As a starting point, the economist could base the YLL calculation on the average characteristics of the beneficiary population. When possible, further disaggregation to incorporate age (younger beneficiaries lose more years of life than older ones) and incidence/death rate by age is desirable to more accurately estimate benefits.

An example helps to clarify concepts. Suppose a WASH project will improve availability of clean water to 10,000 beneficiaries. The "without project" incidence of infectious diarrhea is currently 140 per 1000. The intervention is expected to reduce incidence by 40%, so the "with project" incidence rate will be 84 per 1000. Every case of infectious diarrhea has an associated 0.5% chance of death, so the number of deaths "without project" is  $0.5\% \times 140 = 0.7$  deaths per thousand, while deaths "with project" is  $0.5\% \times 84 = 0.4$  deaths per thousand. Thus, the intervention will prevent 0.3 deaths per thousand of beneficiaries. The present discounted value (PDV) of future earnings from the average beneficiary at the time of death, multiplied by the number of deaths prevented, is the annual benefit from the intervention. If the project has 10,000 beneficiaries, it will prevent 3 deaths each year. If the PDV of future earnings is \$100,000, then the benefit stream is \$300,000 per year.

Another commonly used method to assign value to life lost to disease and disability is to use the value of a statistical life (VSL). This method has the advantage of being derived from the value victims of disease put on their own life themselves, rather than valuing people in terms of the income they earn (putting a lower value on the lives of relatively poor people). Since using VSL has become standard practice in CBA in high and middle income countries, we are investigating some suggested approaches for adopting VSL for our purposes. The results of our investigation will be described in the next iteration of this guidance.

## Other Diseases

The other diseases besides diarrhea can have labor productivity losses besides loss of life. In cases where

the lower labor productivity is primarily a result of work days lost, the economist should assign a value to that using the beneficiary's opportunity cost of time. In cases where the illness does not result in lost work days, but rather lower labor productivity overall, the economist can use the opportunity cost of time of "years lost to disability" (YLD).

Calculating an additional YLD component follows a methodology similar to that described above for the YLL component. The main difference is that we use the value of time spent with disability avoided, instead of the value of deaths avoided, as the annual benefit stream.

For example, suppose the WASH project described in the previous example is expected to significantly reduce schistosomiasis in the beneficiary population. The "without project" incidence of schistosomiasis is currently 90 per 1000. The intervention is expected to reduce incidence by 40%, so the "with project" incidence rate will be 54 per 1000. Every case of schistosomiasis has an associated 0.004% chance of death, so the number of deaths "without project" is  $0.004\% \times 90 = 0.0036$ , while deaths "with project" is  $0.004\% \times 54 = 0.0022$ , so the intervention prevents 0.0014 deaths per thousand. If the project has 10,000 beneficiaries, and the PDV of future earnings is \$100,000, the benefit stream from deaths avoided is \$1,400. Furthermore, each incidence of schistosomiasis lasts for 3 years, with a disability weight of 0.006, resulting in the equivalent of  $3 \times 0.006 = 0.018$  years of life lost. Reducing the incidence of schistosomiasis from 90 to 54 per thousand results in a reduction in YLDs of  $36 \times 0.018 = 0.648$  per thousand. If the value of YLDs is approximately equal to per capita income, and per capita income is \$10,000, then the reduction in YLDs generates \$64,800 in benefits each year (from the 10,000 beneficiaries). The benefits from reducing incidence of schistosomiasis clearly come mainly from reducing the disability side of the health effect.

In these examples, the benefits from reducing incidence of schistosomiasis are significantly lower than those from reducing incidence of infectious diarrhea. As other diseases tend to have even lower combinations of prevalence, death rate, and disability rates compared to schistosomiasis, it may be sufficient to limit the ERR calculation to benefits associated with the top two or three most costly water-borne diseases in the relevant context. In some contexts, substantial malaria benefits may accrue from a drainage project, and including these would be important in those cases.<sup>21</sup>

### Calculating and Valuing Lifetime Earnings Lost to Stunting

Cases of infectious diarrhea that occur in young children aged 0-2 can produce stunting, which typically leads to children entering the educational system a year later (reducing their overall education) and entering the workforce later (reducing their lifetime earnings).<sup>22</sup>

The core of this methodology is a Mincer regression that can assign relative returns to extra years of work experience and education. Since Mincer regressions are standard tools used in Constraints Analyses, a Mincer regression will already be available for most compact countries. We recommend using Mincer regressions that have applied the standard MCC methodology.<sup>23</sup> The returns to education are combined with the effect that infectious diarrhea cases have (through malnutrition) on stunting. Teshome et al. (2009) find that "children [aged 0-5 years] experiencing diarrhea were 2.3 times more likely to be stunted compared to the reference category (i.e., children without diarrhea)."



See Appendix 3 for an example that uses the odds ratio in Teshome et al. (2009) to determine the expected reduction in stunting.

### 3.2 Time Savings Benefits

One of the main benefit streams associated with WASH projects is time saved gathering water. The benefit of decreased time spent gathering water is measured by comparing time spent with and without the project and multiplying that difference by the value of time of the beneficiaries.

In a standard household utility maximization model, in an interior solution with no barriers to entry to the labor market, the household will allocate time across leisure, home production, and time spent earning a wage such that the marginal value of all the activities is equal. In that case the opportunity cost of time of a given family member is equal to the wage they would earn in the market.

When there are barriers to entry, it may not be optimal for the utility maximizing household to assign family members with lower marginal labor productivity to wage earning activities, even when the market wage is somewhat higher than the marginal value to the household of those family members engaging in home productivity or leisure. Since households typically assign the low productivity family members (i.e. women and children) to collecting water, using the market wage may overestimate the value of time in the presence of significant barriers to entry. Employment indicators, like the difference between genders in labor force participation rates, could be an indicator of whether this is a problem. In countries where the gender gap in labor force participation (LFP) is particularly wide, the team economist should suggest the project also address women's access to the labor market – it won't help the household as much if all the freed up time is spent, involuntarily, on leisure or low productivity household production because of exogenous barriers to working. Another way to reflect the relative size of exogenous barriers to entry for women is to use the difference in LFP rates between genders to discount market wages, if the country team agrees this is necessary.<sup>24</sup>

Because the market wage for children is sometimes not collected by labor force surveys, and the resulting wage probably does not reflect the opportunity cost of time spent in educational activities, we recommend the economist value children's time as equivalent to the time of adult women in the household.

Absent indicators of significant barriers to entry to the labor market, women's time can be reliably measured by their wage. The first best method to collect women's wage information is to conduct a wage survey of the beneficiary population targeted by the project, although the compact development timeline typically does not allow enough time to do this. The second best source of wage data would be from a recent labor force survey, if available. Absent that, the average wage (of unskilled labor, if available) for women from a labor force publication can be used.

Use caution in using an administratively-set minimum wage, since it often significantly overestimates the unskilled wage rate and is likely imperfectly enforced.

Absent an estimate of targeted beneficiaries' wages, the economist should endeavor to construct a value of

work from available sources that is a defensible proxy for the average income per hour of either the project's beneficiaries or of unskilled labor, in similar economic activities to those in which they are already engaged.

### 3.3 Cost Savings

In addition to time savings and health benefits, consumers of water and sanitation services may experience lower prices per unit of consumption. This could arise through substitution away from bottled water, or the reduced use of storage tanks and/or more costly drilling for ground water. This benefit, when applied to the original consumption level, is theoretically equivalent to an increase in real income, without double counting the benefits of increased water consumption on health.

### 3.4 Consumer Surplus Approach

MCC prefers to utilize income-proximate methods described above to quantify benefit streams of WASH projects. However, there may be times when estimating the individual benefit streams separately is impractical, likely to miss important economic benefits, and/or is double counting. An alternative method is to measure the total consumer surplus gained as a result of expanded access or improved service. This approach would in principle capture the valuation of all benefit streams accruing to individual households and businesses, including health and time savings benefits, cost savings benefits to businesses and households, as well as the welfare benefit to consumers of having access to an expanded consumption possibility set.

There are two main methods of capturing changes in consumer surplus, depending on whether the good is actively traded on a market. If there is an established history of market transactions of the good in question, the “revealed preferences” technique can be used to estimate willingness to pay for a marginal increase in supply of the product. This is a fairly standard technique described in most microeconomics textbooks. For example, the willingness to pay for the reduction of noxious odors associated with a water treatment plan should be represented in the price tenants and owners are willing to pay to live in neighborhoods where such odors are present. Using differences in rent paid for various objectively measurable amenities – the presence or absence of toilets, electricity, water connections, proximity to sources of noxious odors – is called a “hedonic regression,” a standard econometric technique.

Estimating the willingness to pay for a good for which there is no readily available market data can be more complicated. For example, what is the willingness to pay for lower waterborne disease exposure due to cleaner surface and groundwater supplies? Such benefits tend not to be tied to a specific location and are difficult to measure using hedonic regressions. When an individual household connects to a centralized sewage system, the household's effluent does not enter the groundwater supply, lowering exposure to waterborne diseases for all households accessing water from that watershed. Such “consumption externalities” can be quantified by conducting a survey of household's willingness to pay for lower incidence of waterborne diseases.

The standard technique is to conduct a “stated preference” (alternately, willingness to pay or contingent

valuation) survey. The literature on such surveys is extensive, starting with Mishan 1971, Whittington 1998, NOAA's 2001 guidelines for conducting contingent valuation surveys, Whittington 2002 and Whittington 2010. Also chapter 16 of Boardman et al.'s textbook "Cost Benefit Analysis" provides some discussion of the topic.

Asking businesses their willingness to pay for water can be a good way to measure the induced benefits of alleviating a water scarcity constraint, if business owners have full knowledge of the investment opportunities that improved water availability would prevent. Note, however, that the businesses' willingness to pay is equal to the risk-adjusted present value of profits from the new business opportunities. The value added of expenditures on labor, i.e. the increase in real incomes resulting from the project for the business' employees, would not be captured, but could be modeled using estimates of firms' representative production function from detailed firm surveys.

The project logic will determine the kind of WTP survey to conduct. For example, if the primary goal of the project logic is to induce business investment, the country team should fund a WTP survey of targeted businesses. If the goal is primarily to increase supply of water in a country with relatively little problems with waterborne diseases and time spent collecting water, a WTP survey of households may be more appropriate. Country economists should be aware that a random sample of households will contain business owners, so if WTP of both households and businesses is desired, a well-designed WTP household survey may suffice.

Note that the lack of a market for a good has not stopped MCC from finding "revealed preferences" approaches in the past.<sup>25</sup> If there is no piped water system, expenditures on bottled water, or estimates of the value of time spent gathering water can be used instead of a contingent valuation survey. Often the compact development timeline does not allow enough time for a proper CV study to be performed before an investment decision must be made.

Finally, even if the willingness to pay approach is used, MCC's economic analysis will attempt to understand the nature of the underlying benefit streams. To what extent is the willingness to pay a measure of what would be used by firms for productive uses, versus expanded use by consumers, or for improving health and/or the convenience of access? These distinctions are important for MCC's *beneficiary analysis* to forecast the expected beneficiary impact and to ensure that externalities are properly taken into account without double counting.

### **Benefit Stream: Lower Costs of Water**

Lower costs of water are included as benefit streams in many MCC WASH projects. Lower costs occur primarily when an existing water transmission and distribution network is rehabilitated to reduce physical losses (e.g. leaks), as distinct from non-physical losses (e.g. theft). In such cases the recommended methodology is to estimate the volume of water that will be saved due to the reduction in physical losses and assign to it the per unit price of water charged to customers.<sup>26</sup> If there is a regulatory agency that ensures that any cost savings are passed on to the project's beneficiaries, then these cost savings can be captured by consumers. In other cases, the savings will tend to accrue to the utility and may improve its financial position, sustainability, and ability to improve service in the future.

This points to the potential need to address institutional reform in cases where the utility is determined to be unable to sustain service improvements or pass cost savings to customers. The country team should recommend which reforms are needed to deliver the project's intended results, and whether additional external support is required to achieve the project's objectives. Using conditionality (conditions precedent) to establish a regulatory agency (for example to ensure cost reflective tariffs sufficient for maintenance, overhead, and capital expansion) is unlikely on its own to successfully address governance failures in the sector. If the benefits of the project are primarily increased profits for the utility, then the economist should be careful to identify the project beneficiaries as the shareholders of the utility and not the utility's customers. The need for accompanying policy and institutional reform is discussed further below.

In cases where customers are connected for the first time to a water utility, the reduction in cost manifests primarily as a reduction in time spent gathering water, or expenditures on bottled or delivered water. The recommended methodology in this instance is to deduct the estimated cost of utility bills from the time savings or delivered water expenditures for a net reduction in cost for the beneficiary.

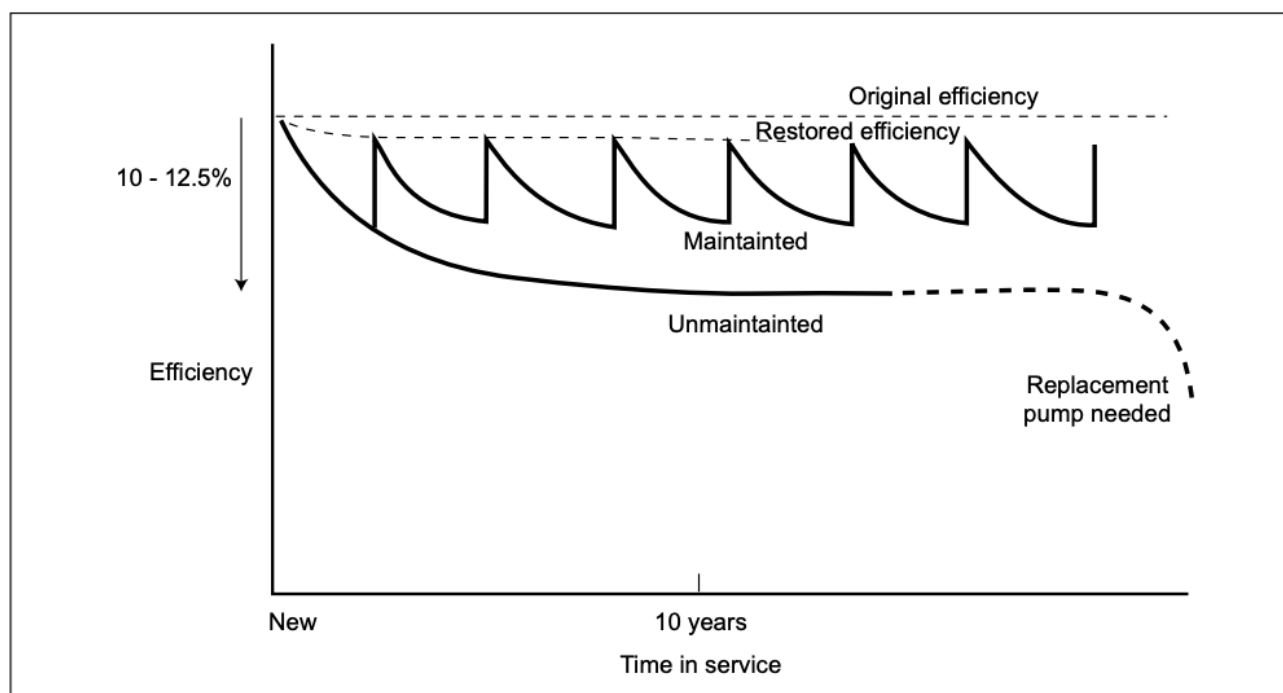
The benefits of improving water quality can include savings on fuel that had been used for boiling water or investments in household treatment systems and consumables. These can include: purchase of charcoal, gas, time spent to gather firewood; purchase and upkeep of household filters, and purchase of chlorination chemicals

## 4. Estimation of MCC WASH Project Costs

As with all CBA at MCC, all costs associated with delivering the project's benefits must be included in the ERR, regardless of who bears them. Infrastructure extension projects incur costs of infrastructure construction,<sup>27</sup> of connecting households to water and sewer lines, and constructing water closets (for sewer infrastructure); potential increased household expenditures on water (balanced against its health and other benefits), and costs of informational programs aimed at changing hygienic practices. Environmental mitigation costs (or damages) are also included.

A crucial assumption on the cost side for MCC CBA is expected future maintenance practices, with and without the project. Typically MCC is asked to build WASH infrastructure where maintenance in the past was poor and infrastructure was allowed to depreciate prematurely.

The purpose of maintenance is to sustain an asset's efficiency, as illustrated in the following figure:



[Energy Savings in Industrial Water Pumping Systems](#), page 9.

Without maintenance crucial equipment must be replaced earlier in the asset's lifecycle than necessary, leading to reductions in quality of benefits the asset provides, and increased expected future costs associated with asset replacement.

Typically in the “without project” baseline, we use a realistic “business as usual” assumption regarding how quickly assets and service levels will deteriorate in the future, basing this on past maintenance and partial replacement practices – with the associated maintenance costs included being those necessary to sustain the current status quo. If there is no reason to expect a change, business as usual maintenance and asset management, and other aspects of utility performance, would also be assumed in the with-project scenario. The “without project” scenario should not assume that similar improvements under the proposed project will take place anyhow, in a few years, under alternative funding. This is because it is the project itself, not the source of funding, which is being analyzed in a CBA.

When WASH infrastructure is improved, another potential source of higher costs is higher rents charged to tenants in buildings with improved plumbing. The associated decrease in affordability can have adverse consequences for the targeted beneficiaries – e.g., the improved infrastructure assets can lead to higher property rents, benefitting property owners but forcing renters to move. The project design and beneficiary analysis should take note of affordability issues and provide alternatives for addressing them, even if there is no efficiency issue.

## 5. Detailed Estimation of Project Benefits

### Measuring Benefits through Consumer Surplus

“Revealed preferences” is a standard methodology described in most CBA textbooks and is not reproduced here. Citations provided above for “stated preferences” methods may also be useful. The “revealed preferences” method tends to be more consistent with MCC’s evidence-based approach than the “stated preferences” methodology.<sup>28</sup> In this section when and whether to use CS methodologies is discussed.

Using consumer surplus methods (both revealed and stated preferences) to estimate benefits of increased consumption of a good in a cost-benefit analysis is standard CBA practice. As mentioned in MCC CBA guidelines, changes in consumer surplus that represent a simple transfer from producers are not counted as a benefit, consistent with standard CBA practice regarding transfers from one economic actor to another.

MCC’s CBA guidelines specify that the goal of MCC projects is to promote growth in real incomes, because growth in income is how we achieve the goals in our authorizing legislation, to promote economic growth and reduce extreme poverty. When it can, MCC economists make a conscious effort to measure changes in real incomes, rather than welfare (as measured by consumer surplus). Sometimes CS methods are the best way to approximate real income changes, and in some instances CS methods are the only way to estimate benefits at all.

In WASH projects, consumer surplus methods can capture cost savings on baseline “coping costs” other than time spent collecting water, and “quality of life” and “aesthetic” benefits from the increased quantity of water supplied by a project. When such benefits are expected to be significant, CS methods may be appropriate. However, when the main component of “quality of life” benefits are for leisure purposes, like taking showers, such benefits might be considered less relevant to MCC’s mission of reducing extreme poverty. CS methods can also capture the benefits of small-scale productive use of water, like in subsistence agriculture, which may be useful, depending on the project.

### **Indirect Benefits (through Induced Investment)**

When increased supply of water can reasonably be expected to induce greater production, employment, and/or investment (vis-à-vis the without project case), and data exists to estimate the appropriate values, it is acceptable to include these induced benefits. *Assumptions would remain conservative*, and the degree of induced economic activity would depend upon findings of a Constraints Analysis as well as the specific context in the country – for instance, whether other constraints that appear binding are being addressed.

### **WASH Policy and Institutional Reform (PIR) Topics**

One of MCC’s lessons learned from past projects is that most major infrastructure projects require an associated policy/institutional reform (PIR) project to ensure that the utility is well managed and asset maintenance improves. Evaluating the need for improvement in the asset maintenance regime is now standard for due diligence of any proposed infrastructure project (see “Economic Analysis of Policy and Institutional Reform Programs: Position Paper and Recommendations for MCC Management,” internal EA guidance). When a PIR project has been deemed a necessary component of the project, then it is considered a required condition for achieving the long-run benefits of the overall project, and therefore its

costs are *included* in the overall project costs. Economists will, in cases where it is feasible to do so, explicitly separate out the costs and benefits of PIR components to calculate a separate ERR (complementarity of benefits being accounted for, where relevant, in the overall ERR). However, regardless of whether this is the case, economists will need to assess, based on the available evidence and experience, the likely trajectory of service and benefits using realistic assumptions regarding both the with- and without- project scenarios.

There is some evidence that governance reforms are central to sustaining improved performance in the water and sanitation sector, and that in particular private sector participation and independent regulation result in improved sustainability, quality of service, costs of service, and investment levels (see Andr  s et al. 2013). Serious discussion about this and other evidence, the context, and the problems faced in the sector should be part of compact development to ensure that MCC investments are cost-effective and that impacts are sustained.

According to MCC’s sustainability guidelines, the country team should engage in a discussion of assumptions and risks that threaten the sustainability of the project’s results. The team economist should ensure that the team considers PIR issues in this discussion.

Several questions should be considered regarding the potential need for PIR investment. If the MCC project is building a large infrastructure asset, this is an opportunity for MCC to ask questions about how the asset came to be needing building/replacement in the first place. The three main variables to consider in PIR for a WASH project is tariff levels, physical losses, and commercial losses.

- For a water utility charged with maintaining a water network, is the tariff set at a level where the utility can recover the costs of repairing existing infrastructure and to cover expected future expansions of the network?
- Is the fiscal outlook for the utility sound, with a sustainable debt level and capacity to service it? Are liabilities of the public utility recognized in the government’s debt management strategy as quasi-fiscal liabilities of the public sector overall?
- Does the utility track the location and age of its assets and have a maintenance/replacement plan for them?
- What is the rate of physical and commercial losses? Does the utility track these figures? Is there an acceptable level of losses written into the tariff setting analysis by the utility’s regulator? How was that level arrived at?
- Are there institutional customers who refuse to pay utility bills because of their political power? Does the government set aside funds to pay the utility bills of these institutions? Does the utility have political/legal standing to sue the government for non-payment?
- Who owns the utility (is it government owned, a PPP, privately owned, other?)? is the owner of the utility invested in its sustainability? Would fundamental changes to the owners’ incentives (e.g. privatization, or establishment of a locally elected governing body) incentivize the utility’s owner to be more invested in its sustainability?

Any combination of high physical/commercial losses and non-cost recovering tariffs can lead to eventual financial failure of the utility, which must be bailed out by the government, either explicitly by raising government funds, or implicitly by legally requiring the utility to continue providing services, even though the tariff is set too low for the utility to be commercially viable. The latter is often called an implicit

subsidy (or a “contingent liability”). Ideally such implicit subsidies should be identified in program design and appropriate reforms introduced. In cases of significant implicit subsidization, the country team, and the team economist in particular, should discuss during compact development whether the fundamental incentive structure of the utility should be changed. Note that public subsidies to utilities to support social or economic priorities of the government should at least be publicly recognized, transparent (contractual), and explicit in the budget of the government and public utility. If possible, subsidies for social or economic purposes should be removed from the utility’s budget entirely and administered by an agency completely independent of the utility.

It should be noted that there is no reason the issue of addressing implicit subsidies must be accompanied by an infrastructure project. Improving the commercial viability of a water utility can be a standalone project. If the proposed changes are politically difficult, adding an infrastructural piece to the project may give the compact country additional political leverage to sell the necessary changes.

Some WASH projects MCC has worked on involve significant physical losses. Reducing physical losses has the same effect as reducing costs per unit of water supplied and can be analyzed from a cost reduction perspective. However, physical losses that reach a certain extreme extent – say, greater than 50% – are an indicator of significant institutional weakness. Such high levels of losses will almost certainly be accompanied by either explicit or implicit subsidization.

Other WASH projects have involved utilities with significant commercial losses. A commercial loss is when a utility sends water through its network to someone who consumes the water but does not pay for it. While the (immediate) resulting net welfare is the same as the case without theft – the cost of producing the water is the same, and the consumer’s marginal welfare from consuming the water is the same – the transfer of revenue from the utility to the consumer harms the long run financial sustainability of the utility, which is often the root cause of the utility’s problems. EA is currently developing a methodology for measuring the benefit to long run sustainability that results from the reduction of commercial losses.

In addition to assumptions captured in the project logic, teams should spend some time brainstorming additional, implicit assumptions and risks pertinent to the sustainability of compact investments, including risk mitigation options. We do our best to enter into implementation with comprehensive project logics, but it is important to validate our design assumptions at the outset, and confirm that we have not missed any major opportunities to build greater sustainability into our designs. The five pillar model of sustainability can be a good starting place for this task. Some additional questions to consider are:

- Sequencing: for projects with activities and sub-activities that build on one another, what is the potential impact of delays in implementation? How will a one-month (or six-month) delay affect the overall sequencing of the compact? What will the impact be on sustainability?
- Behavior change: to what degree does post-compact maintenance of compact interventions rely on behavior change? Both in terms of infrastructure investments and non-infrastructure investments, whose continued action will be necessary to achieve compact results? By CED, will those individuals have (or have acquired) the necessary skills, resources, and incentives to continue taking action after the compact has ended?



- Uptake: if beneficiaries do not choose to connect to the water network, how will this impact compact results? If we are assuming uptake will continue to increase after compact end date, who will be responsible for continuing to promote uptake among the target of the intervention? Will that entity have the necessary capacity and resources to do so?

This is not an exhaustive list of considerations, and teams should feel encouraged to use the process of completing the baseline assessment to ask obvious or difficult questions.

The question of behavior change and uptake are well understood in MCC now to be critical to achieving project outcomes. Where key benefit streams depend, for example, on people financing household connections to the water, sewer, or electricity grid, the affordability of connections for local beneficiaries is paramount. In other cases behavior change around using new facilities (e.g. shifting water supply sources), civic attitudes to trash disposal, or awareness of proper hygiene practices to prevent the spread of water borne disease are critical to achieving project outcomes. Most projects targeting community level services will require explicit attention to behavior change and uptake.

## Uncertainty

Many of the parameters used to inform WASH CBA are subject to significant uncertainty. MCC's CBA guidelines require EA economists to perform Monte Carlo analysis of ERRs based on simulations around key parameters that are subject to significant uncertainty, as identified by the economist. Uncertainty can be increased markedly and arbitrarily simply by choosing a large number of variables, so the choice of parameters to simulate over is best kept parsimonious and relevant.

If the distribution is roughly symmetric and unimodal, economists should report the most likely ERR (the mode of the distribution), in addition to the probability of it falling below the hurdle rate of return. If the distribution approximates a bimodal one, for example with or without success in achieving PIR, either an expected value ERR could be reported, or two ERRs with an "if, then" statement where the scenarios are well specified.

For WASH CBA, the list of variables subject to uncertainty includes:

- For health benefits:
  - wages,
  - disease incidence reduction,
  - take up of connections to new infrastructure
  - behavior change (e.g. switching from outdoor defecation to latrines or indoor WCs, or using toilets as garbage cans)
  - Other parameters to consider: population of the study area (if no recent census has been performed), case fatality rates, and baseline diarrhea incidence.
- For time savings
  - Wages
  - Time spent collecting water
- For cost savings
  - technical/commercial loss reduction.
  - Elasticity of demand for water

- For PIR
  - Time path and probability of success
  - Sustainability of political commitment to program

## **Public-private Partnerships in the WASH Sector**

As defined by the World Bank <sup>29</sup>, a public-private partnership (PPP) is a long term arrangement in which a private party assumes some authority over a government asset, or agrees to provide a service for a government entity, while bearing a significant share of the risk for the project's outcome. A PPP should therefore be viewed as distinct from privatization in which the government relinquishes control or ownership of an asset entirely.

The WASH sector is dominated by goods that are near-public goods; water and disease resistance are common-pool resources and the heavy infrastructure requirements cause the provision of water and sanitation to be provided through natural monopolies. These goods can be traded in markets, but not efficiently <sup>30</sup>. Often privatization is not a politically acceptable option. An additional complication in the WASH sector arises because access to water is often viewed as a human right and the tariff is often set at or near zero <sup>31</sup>.

## **Productive Efficiency of Public-private Partnerships and the Manila Water Concessions**

Under the right circumstances, PPPs can help with these problems. The private sector has inevitable incentives to reduce costs and collect revenue—both issues which state-owned enterprises struggle to match—but these improved incentives must be balanced against the ability of the contracting authority to enforce provisions of the contract, which requires contract enforcement and procurement capacity that is often not present in developing countries.

The case of the Manila water concessions illustrates these issues well <sup>32</sup>. In the late 1990's, the Manila water utility (MWSS) agreed to separate concession arrangements with two consortia operating the eastern (Manila Water) and western halves (Maynilad) of its network. The two concessionaires each offered tariffs below the initial cost-recovery tariff level, while agreeing to concession fees large enough to cover the utility's debt service. Despite identical initial conditions, the experiences of the two concessionaires diverged massively. Manila Water was able to keep tariffs low, while reducing non-revenue water (NRW) more quickly than contractually required, yet continues to operate profitably. Maynilad was somewhat slower to invest initially. After the Asian Financial crisis, Maynilad tried to raise tariffs to cover increases in the concession fee, resulting in "rate shocks" which decreased public trust. As a result, Maynilad never invested as heavily in its network as Manila water, and eventually, its network was renationalized following bankruptcy.

While there may be many causes of Maynilad's failure, one clear cause was likely the poor risk allocation for these partnerships, which in turn is a failure of Manila's low procurement capacity. Manila Water's initial investments were already sunk by the time concession fees were raised, leaving it with strong incentives to continue network investments.

## Appendix: MCC History

As of the drafting of these guidelines, MCC is monitoring three ongoing WASH projects (in Zambia, Jordan, and Cabo Verde) and six completed projects (in El Salvador, Georgia, Lesotho, Mozambique, Tanzania, and Ghana).

For many of the compacts, health benefits were estimated as the reduction in number of sick days or work days missed. The recommended methodology now is to capture this benefits in the “years lost to disability” (YLD) part of the DALY calculation. Similarly, efforts to assign value to mortality are now subsumed in the YLL part of the DALY calculation.

The recommendation that the opportunity cost of time should be estimated using the average wage of the beneficiary population or, if such data are not available, the estimated wage for unskilled labor, was made after the ERRs for these WASH projects were completed. Nevertheless, many of the wages used in the ERRs came close to the recommended ideal.

Below are descriptions of the various WASH projects and highlighted ERR details of interest.

### MCC Compacts with WASH Projects

Country	Status	Entry into Force Date
Georgia	Closed	4/7/2006
Ghana	Closed	2/16/2007
El Salvador	Closed	9/20/2007
Lesotho	Closed	9/17/2008
Tanzania	Closed	9/17/2008
Mozambique	Closed	9/22/2008
Jordan	Implementation	12/13/2011
Cabo Verde II	Implementation	11/30/2012
Zambia	Implementation	11/15/2013

### Georgia

In Georgia, the WASH infrastructure inherited from the Soviet Union had broken down significantly, leading to clean water being provided only a few hours each day. Households were forced to fill reservoirs with water during the times water was available. Because households had already had clean water, no health benefits were calculated in the ERR. Rather, the main benefits of the project were time savings (from eliminating the need to maintain the reservoirs), valued at the estimated informal wage rate for women.

Link to Georgia I ERRs: <https://www.mcc.gov/where-we-work/err/georgia-compact>

## Ghana

The Water and Sanitation Facilities sub-component of the “Community Services” activity of the “Rural Services” project in Ghana was designed to complement the Agriculture Project by providing water infrastructure in the MCC project areas and enhance the capacity of local governments to deliver water services. MCC funding was used to fund boreholes (both mechanized and hand-pumped), small town pipe systems, pipe extensions, and community sanitary facilities. The main benefits of the project are improved health, reduction in the incidence of illness and loss of productivity due to unsafe drinking water and poor consumer sanitation and hygiene, and to reduce the time required to procure potable water.

Time savings benefits were valued at half the minimum wage and calculated as the reduction in time spent fetching water per day as derived from local household surveys. Health savings were calculated as a reduction in morbidity and sick days, also valued at half the minimum wage.

Link to Ghana I ERRs: <https://www.mcc.gov/where-we-work/err/ghana-compact>

## El Salvador

In El Salvador’s “Human Development Project,” the “Community Development Activity” contains a “Water and Sanitation” sub-activity. The sub-activity designed and constructed potable water systems (e.g., wells and pumps) in more than 20 communities.

A large portion of the population in the Northern Zone of El Salvador lacked access to clean, piped water. The MCC project expanded water access. As households had previously used either trucked water, wells, or river water, the installation of piped water access provided benefits through decreased costs, reduced time spent gathering water, and reduced disease rates. Cost savings were calculated from a Northern Zone 2008 household survey on water source and expenditures, time savings were taken from the same survey’s data on time spent gathering water by source. Time was valued at half the minimum wage.

Link to El Salvador I ERRs: <https://www.mcc.gov/where-we-work/err/el-salvador-compact>

## Lesotho

The Lesotho water sector project is aimed at improving water supply for industrial and domestic needs. It consists of an urban and a rural sub-activity. The urban sub-activity was designed to extend and rehabilitate the urban and peri-urban water network, including extending reticulation to the towns of Semonkong and augmenting supply to the town of Mazenod. The rural sub-activity was designed to improve water supplies and provide ventilated improved pit latrines to small rural settlements.

The benefits for the urban sub-activity consisted of four main streams: (i) time saved in water collection, (ii) time saved in obtaining medical treatment for water-related illnesses, (iii) reduced mortality for children under 5 due to water-related illnesses, and (iv) increases in investment due to greater water

availability.

The analysis calculated the value of time saved on the basis of an estimate of the urban population currently affected by underdeveloped or disrupted water service. This figure, 40 percent, corresponds to the portion of the urban population not having piped in-house water supplies; although one could also expect that a portion of existing in-house customers were experiencing deteriorating water service frequency and water quality. Allowing for urban population growth, the analysis estimated an increasing level of time spent collecting water to represent the deterioration in existing infrastructure and anticipated difficulties in providing full service accommodation for an expanding urban population. The value of time freed for productive activity through the convenience of improved water supply is qualified by the likelihood of employment for urban men and women. It was assumed here that project investments will lead to a halving of the time that would be spent in water collection over time.

Private sector investment to utilize the improved availability and reliability of water in urban areas was also considered, relying in part on results produced in the economic growth modeling for Lesotho recently undertaken by the World Bank. Estimation of the private sector response is based on an assumed relationship between infrastructure and private investment and the ratio of value added to incremental investment.

Link to Lesotho ERRs: <https://www.mcc.gov/where-we-work/err/lesotho-compact>

## **Tanzania**

The MCC activities were focused in two regions of Tanzania. In Dar es Salaam, the “Lower Ruvu Plant Expansion” expanded the capacity of the Lower Ruvu water treatment plant, and the “Non-Revenue Water” activity was intended to significantly reduce physical and commercial water losses in the Dar es Salaam system. In Morogoro, MCC rehabilitated and upgraded two water treatment plants there, and had planned to improve the existing distribution network.

In Tanzania, a large portion of the population lacked access to clean, piped water. Furthermore, water supply could not fully satisfy business demand for water in those areas with access. The MCC WASH project sought to expand water access for residential households and increase the water supply (and therefore the duration of water access per day) to some commercial districts. In the residential districts, benefits included time and health savings for households, since clean piped water takes less time to gather than well or river water and reduces the frequency of waterborne illnesses. Time savings were valued at half the minimum wage while health savings were valued at the reduction in DALYs. For commercial districts, benefits were measured through a consumer surplus model based on the current price of water and an assumed linear demand curve.

Link to Tanzania ERRs: <https://www.mcc.gov/where-we-work/err/tanzania-compact>

## **Mozambique**

In Mozambique MCC expanded access to water and sanitation facilities in numerous towns and provided

boreholes to provide clean water for rural households. Benefits were time savings, valued at the average wage as shown through a consumption survey from 2006 and calculated as the reduction in time spent fetching water per day. Health savings were calculated as a reduction in morbidity and sick days, also valued at the average wage through consumption surveys.

Link to Mozambique ERRs: <https://www.mcc.gov/where-we-work/err/mozambique-compact>

## Jordan

The proposed Compact program consists of three tightly-integrated infrastructure projects that address critical problems in water distribution, wastewater collection and wastewater treatment. The projects are focused in Zarqa Governorate, home to the country's second and fourth largest cities, Zarqa and Ruseifa, and to the majority of the country's small-scale industry.

The Zarqa Governorate Water Network Restructuring and Rehabilitation Project (Water Network Project) is designed to reduce high water losses by repairing and upgrading transmission and distribution pipes throughout Zarqa and Ruseifa. The project includes direct assistance to poor households to improve plumbing, water storage, sewage connections, and general awareness of best practices for sanitation and water efficiency.

The Wastewater Network Reinforcement and Expansion Project (Wastewater Network Project) is designed to rehabilitate sewer main lines that are nearing capacity and extend service to approximately 18,000 households, for a total of 100,000 people that are not currently connected to the sewer network. This will improve wastewater services, prevent potentially harmful overflows of raw sewage, and capture additional quantities of wastewater for eventual reuse in agriculture downstream in the Jordan Valley.

The As-Samra Wastewater Treatment Plant Expansion Project (As-Samra Expansion Project) is designed to expand the capacity of the existing As-Samra Wastewater Treatment Plant by an additional 97,800 cubic meters per day, an increase of more than one-third, which is projected to be sufficient to meet the wastewater treatment needs of large populations in Amman and Zarqa Governorates at least through 2025.

Benefits from the Water Network Project are based on improvements in the efficiency of water supplied to the region's urban population. At present, most households receive water through the public water network only once or twice per week, and many purchase bottled water or tanker truck water to supplement their consumption. Repairs that make more water available through the public network should allow many consumers to reduce their reliance on these costly sources of additional water, thus reducing household expenditures on water or allowing increased water consumption without changes in cost. Reductions in water losses also mean that the region's limited water supply could serve its growing population over a longer period, effectively shifting the water "supply curve" outward.

The principal benefits from the Wastewater Network Project and the As-Samra Expansion Project accrue from increased efficiency in the use of available surface water, particularly in agriculture, which consumes a large share of water resources. In an effort to prioritize municipal and industrial users, the GOJ has

invested heavily in collection, treatment, and conveyance systems that “free up” fresh water used in irrigated agriculture and replace it with high-quality treated wastewater.

Link to Jordan ERRs: <https://www.mcc.gov/where-we-work/err/jordan-compact>

## **Cabo Verde II**

The Cabo Verde II WASH project has three components: 1) National Institutional and Regulatory Reform Activity; 2) Utility Reform Activity; and 3) WASH Infrastructure Financing Activity.

The national-level reform is designed to improve planning for maintenance and infrastructure improvements, and also to ensure that tariffs are set so as to cover maintenance and capital expansion costs. The utility reform is designed to restructure municipal utility departments into financially and administratively independent corporate entities. The infrastructure financing facility provides seed funding for infrastructure capital improvements. It is also designed to reward utilities for adopting commercial principles.

Link to Cabo Verde II ERRs: <https://www.mcc.gov/where-we-work/err/cape-verde-compact-ii>

## **Zambia**

Zambia’s WASH project will rehabilitate the central water system in Lusaka, extend the water supply infrastructure in one region, extend the combined water and sanitation infrastructure in another, and improve the drainage system in a third region.

Rehabilitating the central water system and extending the water supply infrastructure will reduce the need for women and children to spend time collecting water, either because of intermittent water outages or lack of connection to the central water infrastructure. Increased access to clean water should also reduce the incidence of water-borne disease (primarily infectious diarrhea). Improving the central water system will also reduce leaks, and institutional reforms (particularly installing pre-paid meters) should reduce the accumulation of arrears and improve the overall collections ratio. Improved financial performance of the Zambia utility should lead to lower water costs for the project’s beneficiaries. The drainage project will reduce the incidence of disease by reducing pedestrian exposure to contaminated flood waters.

Health impacts are measured in the ERR by estimating the reduction in DALYs lost to disease, valued at the average Lusaka wage discounted by the overall urban Lusaka unemployment rate. Time savings for women and children carrying water is valued at the average women’s wage in urban Lusaka, discounted by the urban Lusaka unemployment rate for women. Cost reductions in water production are measured by the billable value of the reduction in commercial and non-commercial losses.

The Zambia ERR also estimates the value of reduced property damage and value added for businesses as a result of the drainage project, although the value of these benefit streams is very small, about 1% of overall benefits.

The original ERR for the drainage project estimated significant benefits from reduction of malaria incidence. However, when more disaggregated data became available for Lusaka proper, it was discovered that the incidence of malaria there was almost zero (about 5 per thousand instead of the originally estimated 120), and accordingly the benefits from reduced exposure to malaria were reduced significantly.

Link to Zambia ERRs: <https://www.mcc.gov/where-we-work/err/zambia-compact>

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## Appendix 1: Technical Example for Calculating Benefits from Reduced Stunting

In this appendix we use Teshome et al's odds ratio to calculate the estimated reduction in stunting resulting from the project's reduction in incidence of infectious diarrhea.

For the purposes of the ERR we need the difference in probability of being stunted with and without exposure to diarrhea as an infant. I.e. we need  $P(\text{stunted}|\text{diarrhea})$  and  $P(\text{stunted}|\text{no diarrhea})$ .

In Zambia, we know the overall prevalence rate of diarrhea: 0.483 (almost half of all children will have diarrhea during the course of a year). We know the overall prevalence rate of stunting in Zambia is 0.372. We also know the Odds Ratio of Teshome et al: 2.289. We therefore have enough information to calculate the probability of stunting conditional on diarrhea exposure.

The joint probability of stunting given exposure to diarrhea is:

$$p_{11} = \frac{1 + (p_{1\cdot} + p_{\cdot 1})(R - 1) - S}{2(R - 1)}$$

where  $p_{11}$  is the joint probability of being exposed to diarrhea and being stunted,  $p_{1\cdot}$  is the overall prevalence of diarrhea,  $p_{\cdot 1}$  is the overall stunting prevalence,  $R$  is the odds ratio, and  $S$  is:

$$S = \sqrt{(1 + (p_{1\cdot} + p_{\cdot 1})(R - 1))^2 + 4R(1 - R)p_{1\cdot}p_{\cdot 1}}$$

Once  $p_{11}$  is calculated (0.227) we can get the rest of the joint probabilities trivially:

Joint probability:	Stunted	Not Stunted
Diarrhea	0.227	0.256
No Diarrhea	0.145	0.372

And thus the conditional probabilities:

Probability of stunting conditional on diarrhea exposure:	Stunted	Not Stunted
Diarrhea	0.471	0.529
No Diarrhea	0.280	0.720

In Zambia, a child who endures a case of infectious diarrhea has a 47% chance of being stunted, vs a 28% chance for a child that has not had any diarrhea. Each incidence of infectious diarrhea in a young child

that is avoided (due to the project) reduces that child's chance of being stunted by  $47\% - 28\% = 19\%$ .

We use this core parameter to estimate the reduction in the number of stunting cases that would result from the anticipated reduction in incidence of infectious diarrhea resulting from the project.

If the intervention reduces cases of diarrhea by 42%, then the number of cases of diarrhea among young children will decline from 483 to 280 per 1000. Thus, the chance of stunting for 203 out of 1000 children goes down 19%. In other words, we expect the number of stunting cases to decline by  $203 * 0.19 = 38.6$  per thousand of young beneficiaries (aged 0-5) impacted.

Now we must assign a dollar value to each stunting case prevented. The definition of stunting is growth that is two standard deviations below the worldwide mean (according to WHO). Alderman et al. (2006) found that a one standard deviation decline in height is associated with entering school half a year later, thus delaying entry into the workforce. They also found that the average number of grades attained declines by 0.74. Consequently, a child who is two standard deviations below the mean in terms of height should enter the workforce one year later, and attain 1.5 years less schooling. With a Mincer regression in hand that assigns values to earnings associated with these increments, we can estimate the effect on lifetime earnings associated with one incident of stunting.

Equation one below is an example of a Mincer equation showing the returns to years of education and experience (Exp), respectively.

Equation one: Sample Mincer Equation

$$\ln(\text{Annual Salary}) = 1000 * [0.15 * \text{Exp} - 0.002 * \text{Exp}^2 + 0.1 * \text{Education}]$$

If the average worker has 5 years of education and 15 years of experience, the salary of the average worker will be  $1000 * \{\exp[0.15 * (15) - 0.002 * (15)^2 + 0.1 * (5)]\} = 10,000$ . The annual salary of an otherwise average worker who suffers from stunting will be  $1000 * \{\exp[0.15 * (14) - 0.002 * (14)^2 + 0.1 * (3.5)]\} = 7,800$ .

NB: Each year after the intervention a certain number of stunting cases will be eliminated. Therefore, the benefits of the intervention in a given year is the PDV of the lifetime earnings saved by preventing each case of stunting that year. In the above example, discounting the average savings of 2,200 over a 45 year working life yields a PDV (at 10% discount rate) of 21,100. If 1000 of the 10,000 beneficiaries are aged 0-5, then the total benefit from reduced incidence of stunting in a given year will be  $38.6 * 21,100 = 814,460$ .

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## Endnotes

1. This can interact with any credit market failures that would preclude private customers from financing their connections.
2. Other market failures associated with WASH projects are the fact that some kinds of WASH infrastructure may have natural monopoly characteristics (Teeple & Glyer 1987), and that poor WASH customers face access to finance issues when confronted with large connection fees. Other authors have cited a principal-agent issue as well: A deciding parent is generally not a perfect agent for child principals, who have neither information nor the ability to defend any of their interests that may diverge from their parents' (Munro, 2001.)
3. Usually this is either Information, Education and Communication (IEC) or Behavior Change Communication (BCC) campaigns that can include interpersonal communication (IPC), TV, radio, newspaper and social media (FB, internet). It should be an integral and interactive part of WASH programs, and developed through research on beneficiary behavior, and activities for changing behavior.
4. If the degree of behavioral change cannot be accurately predicted, the CBA model should still include explicit assumptions that can be tested, e.g. a calculated breakeven point for a reasonable return could be used. This could subsequently be tested for in both the monitoring and the evaluation.
5. Note that the effects of flooding are a 'public good' in the strict sense used in the economics literature (non-rival – one business'/household's use of flood prevention does not reduce other's ability to benefit from it, and non-exclusive – there's no way to prevent businesses/households from benefiting from flood prevention).
6. Generally speaking, what distinguishes an *assumption* from a *result* is that the latter lies within a project's "manageable interest."
7. For example, in the Zambia compact, the water utility is analyzing ways to help beneficiaries finance connecting to the new infrastructure built by the compact in the "Sanitation Connection Action Plan," which was a condition precedent for the project.
8. It is also possible for water projects to provide benefits to industrial users of water, but no MCC WASH project has ever explicitly, directly, and deliberately targeted an industrial user – there is no obvious externality associated with industrial use of water, so no need for government/donor assistance.
9. See Beneficiary Analysis guidelines.
10. Economists should collaborate with MCC infrastructure experts during the due diligence stage of the compact development process to collect this data.
11. Although some species of mosquitoes that carry malaria will only breed in clean water.
12. Dengue, an urban disease that is on the rise due to rapid urbanization and climate change, is also carried by mosquitoes.
13. That is, all WASH projects except for drainage projects, which also have the potential to affect malaria incidence.
14. "Incidence" for purposes of these guidelines is defined as expected number of new cases per year per thousand people at risk. It is not to be confused with "prevalence," the proportion of cases in the population at a given time, although at times it is necessary to use prevalence rates in place of incidence rates when the latter are not available.
15. This study is a good source for economists interested in learning more about project logics for WASH interventions.
16. Available on the internet at <http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2876116>.
17. The DALY methodology was developed for the WHO's 1990 "Global Burden of Disease" and has

- been updated and expanded several times since then. See [http://www.who.int/healthinfo/global\\_burden\\_disease/gbd/en/](http://www.who.int/healthinfo/global_burden_disease/gbd/en/)
18. See “Mincer Regression Guidelines” by Andrew Carter.
  19. Available on the internet at [http://www.who.int/healthinfo/global\\_burden\\_disease/GBD2004\\_DisabilityWeights.pdf?ua=1](http://www.who.int/healthinfo/global_burden_disease/GBD2004_DisabilityWeights.pdf?ua=1)
  20. Adding the value of work days lost is a permissible method for capturing disability-related benefits, although the relative size of that benefit tends to be small compared to the YLL value in the case of diarrhea. The economist should use their best judgement when deciding to invest resources in collecting data for a “work days lost” estimate.
  21. Although not the Zambia project, since malaria incidence in Lusaka has been reduced to effectively zero.
  22. See Alderman, Hoddinott, & Kinsey (2006:21) and Bigsten et al. (2000: Table 5, p. 809).
  23. Described in the (forthcoming) Education Project Guidelines.
  24. The logic being that, absent barriers to entry for women, the LFP rate would be the same, and furthermore that the higher the barriers to entry are, the greater the difference in LFP rates will be.
  25. See, for example, the Malawi power sector ERR. Also there are several WASH ERRs that use expenditures on bottled water as a “revealed preference” for WTP for piped water.
  26. Often country economists have data on NRW losses but not the breakdown between physical and non-physical losses. In the absence of data it is permissible for economists to assume 20% of NRW losses are non-physical, consistent with assumptions in the Zambia and Tanzania I ERRs.
  27. For the purposes of the *ex ante* ERR, the costs associated with upgrading a utility’s central infrastructure consist entirely of engineering estimates of the cost of infrastructure construction and ongoing maintenance.
  28. Meaning peer reviewers will set a relatively high bar for accepting benefit streams from “stated preference” surveys.
  29. See “Public-Private Partnerships Reference Guide” from the World Bank et al. for a more thorough treatment, available at [documents.worldbank.org/curated/en/2014/01/20182310/public-private-partnerships-reference-guide-version-20](http://documents.worldbank.org/curated/en/2014/01/20182310/public-private-partnerships-reference-guide-version-20).
  30. Either because the private sector will over-exploit the resource, or because firms will charge monopoly prices for access.
  31. See: Roth, A. “Repugnance as a Constraint on Markets” JEP 21 3, pp37-58 (2007).
  32. See: Wu, X., and Malaluan, N.A. “A Tale of Two Concessionaires: A Natural Experiment of Water Privatization in Metro Manila”, *Urban Studies*, 45(1), 2008